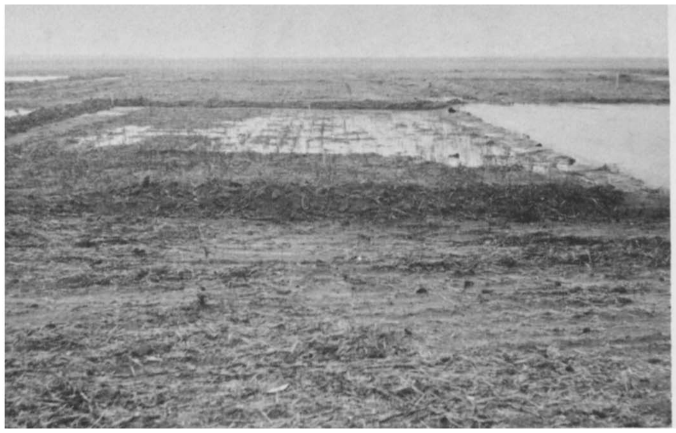
Upslope view of the concentration of induced runoff during the barley growing season.



Concentration of induced runoff onto leveled area before crop planting.

Dryland Agriculture in California . . .

GRAIN CROPPING WITH WINTER RAINFALL

R. E. LUEBS

THE TERMS DRYLAND and dry farming are used in the United States to characterize agriculture existing on an average annual precipitation of from 10 to 20 inches. A high variability in the annual amount is common in these relatively low rainfall areas—less than half the long-time average can occasionally be expected. On the basis of seasonal water availability for vegetation, dryland farming extends from areas where economically useful vegetation is barely sustained, to areas where drought is only an intermittent problem.

Relatively few crops will produce economically under dryland conditions. Most such cultivated areas are devoted to wheat or barley. In a given year, 45 per cent of the California dry farmed lands used for cereal cropping will be fallowed, 45 per cent will be cropped for grain, and 10 per cent for cereal hay. In the semi-arid West, large areas of rangeland (generally considered apart from cultivated drylands) are similarly restricted in forage productivity by lack of water.

According to a recent survey, over 1.8 million acres of land in California are devoted to dryland grain farming. This is a conservative estimate because it considers only California counties with more than 10 thousand acres of drylands. Dryland farming areas extend the entire length of the state from 33° to 42° North latitude. The Central Coast and Sacramento Valley dryland areas are the largest in the state, followed by the San Joaquin Valley, the south and the northeast. Open rangeland in California has been estimated at approximately 10 million acres.

Annual distribution of precipitation in California is distinctly seasonal. In most of the state, 70 per cent of the average annual rainfall occurs during the months of December, January, February, and March. Monthly precipitation in November and April may be significant for non-irrigated vegetation during some years. Precipitation during the remaining six months is of practically no importance to dryland agriculture.

If soil did not have a certain—albeit transient—storage capacity for available water it would be impossible to grow economic vegetation with rainfall as the sole water supply. Texture and depth of soil are closely related to water holding capacity and are, therefore, of much importance in dryland agriculture. About one-half of the dryland acreage in California is on moderately-fine to fine-textured soils. The remaining one-half is almost evenly distributed between medium- and moderately coarse-textured soils. Ninety per cent of the dry farmed area has soil deeper than 2 ft. Approximately 45 per cent has a depth between 2 and 3 ft. A similar percentage is between 3 and 5 ft deep or deeper. Land slope is an important consideration in land use. Generally, dry farmed lands have greater slopes than irrigated lands in California. Approximately 70 per cent have slopes between 5 and 25 per cent. One-half of this land has slopes between 10 and 25 per cent. Twenty-five per cent of the drylands have slopes of less than 5 per cent.

In the winter rainfall climate of California, herbaceous vegetation is dependent on rainfall distribution in at least three important ways: (1) the growing season for dryland crops and range vegetation each year is determined by the beginning and ending of significant rainfall; (2) within-season variation in rainfall is great; and (3) the decline of rainfall at end of season occurs at a time when dryland vegetation is in the period of highest evapotranspiration and plants are in the critical flowering stage.

After the dry, essentially rainless summer period, residual soil water from fallowing is not retained close enough to the surface to germinate seeds in most areas. Several bare soils of widely different textures were wetted to a depth in excess of 4 ft before the summer period. After 12 weeks there was essentially no available water in the 0 to 6 inch depth of all soils. Under these conditions, the growing season cannot begin until the current rainfall season is initiated with significant rainfall (i.e., in excess of approximately 0.5 inches). During some years the growing season is delayed beyond the optimum date for emergence of the crop.

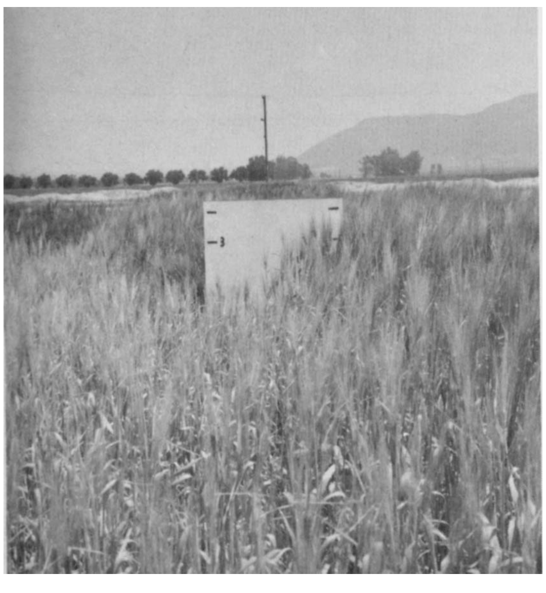
Analysis of 40 years of rainfall data at Riverside has revealed that nearly every year no significant rainfall will be received during one of the four major rainfall months. At the beginning of each rainfall season the probability of occurrence is nearly the same for each of the four months. Dry periods of a month or longer can usually be expected to result in water stress on the dryland crop.

Except for the northeast area, dryland cereals are planted between November 15 and January 15, and do not mature until late May or June. During the last 12 weeks of the growing season the probability of rainfall decreases and the probability of greater plant moisture use through evapotranspiration increases. Evapotranspiration increases because the crop presents a greater transpiring surface and because meteorological factors increase the evaporative demand. Most dryland crops and range plants enter the critical flowering stage at the beginning of this period. The average total rainfall in California dryland areas is usually insufficient to permit maximum grain yields. There is also good evidence that the water received as rainfall is inefficiently used and that this largely results from the failure of precipitation distribution to coincide with the evapotranspiration requirement.

Fallowing the land to increase the storage of water in the root zone of the soil is an old practice in dryland farming areas. It is used for almost all dryland grain cropping in California today. To some degree the water stored in the soil by fallowing prevents or reduces water stress in crops during long dry periods in the first half of the growing season, or during the consistently high evaporative period in the later part of the season. The efficiency of soil water storage with the fallow practice is, however, very low, less than 20 per cent in the moderately coarse-textured soils of southern California.

Because of the very high annual variation in rainfall, the amount of water stored by fallowing fluctuates widely from year to year with almost no storage in some years. An attempt has been made to maintain a higher level of available water in the root zone during the growing season in an 11-inch rainfall area by impounding natural runoff and induced runoff on the land. Recently the following systems were compared: (1) the cropping of all the land every year with natural runoff occurring on a portion of the area and impounding runoff on the remainder; (2) the fallowing of half the land and cropping in alternate years; (3) the induction of almost 100 per cent runoff from one-half of the land and impounding the runoff water on the leveled remaining half which was cropped every year.

Response of dryland barley to concentration of natural runoff; runoff area on the left and concentration area on the right.



The soil was Hanford sandy loam with 2 per cent slope. Natural runoff was controlled on annual cropping and fallow plots by constructing borders around plots which were 25 × 50 ft. The smallest dimension was in the slope direction. Soil water storage at crop tillering and heading was highest with the induced runoff or rainfall concentration system. At crop heading an average of 1.5 inches more water was stored in the 3-ft depth of soil with the induced runoff concentration system than with the other systems.

Barley yields

Barley grain yields with this system were comparable with those after fallow in 1967, 20 per cent higher in 1968 and 19 per cent higher in 1969. On annual cropping plots, barley yields were increased 94 per cent in 1967, 9 per cent in 1968 and 59 per cent in 1969 by impounding natural runoff. The pounds of grain produced per inch of rainfall has been highest with impounding of natural runoff and cropping annually. Concentrating all induced runoff on half the land area and cropping every year provides for a higher rainfall-use efficiency than where natural runoff is permitted and all the land is cropped every year. Inasmuch as some water was not impounded and some drained through the root zone where induced runoff was concentrated, using a smaller contributing area probably would increase rainfall use efficiency with this system.

Because impounding excessive water during the crop growing season can be deleterious to crop growth, some control of runoff may be necessary. The most hazardous period is between planting and emergence of the seedlings when crusting of the soil surface may prevent establishment of a satisfactory plant population. To benefit from the increased stored water, nitrogen fertilizer must be applied under annual barley cropping.

Total nitrogen content of surface soils in many dryland cropping and range areas is low—less than 0.1 per cent. Vegetative growth response to applied nitrogen is marked when adequate water is available. Forage yield increases of 1120 lbs per acre, or 70 per cent, have been measured on rangeland with 120 lbs of nitrogen and 16.5 inches rainfall. Average yields of pasture forage on long-time cultivated soils have been increased the equivalent of 1250 lbs per acre with 35 lbs of nitrogen and an average annual rainfall of about 10 inches.

Nitrogen response

Dryland barley also shows a marked vegetative growth response to nitrogen. Nitrogen applications equivalent to 40 and 80 lbs per acre increased the leaf area 44 and 109 per cent, respectively, of annual cropped barley. This was with adequate water, and before stem elongation. Straw yield at maturity was 1600 lbs per acre greater with the 40-lb rate. Early vegetative growth response to nitrogen resulted in higher evapotranspiration and a greater rate of soil water depletion. Water stress on plants two weeks prior to, and after flowering, decreased grain yield 1300 lbs at the 80-lb rate of nitrogen with total rainfall of 10.8 inches. Yield was increased 400 lbs at the 40-lb rate.

In summary, greater use of the root zone for storage of water is necessary to reduce water stress on dryland crops during long dry periods, as well as at critical growth stages. Holding all or nearly all rainfall on the land and cropping annually with the application of nitrogen fertilizer will probably use rainfall more efficiently than the fallow-crop system in many areas. On gently sloping lands construction of borders at relatively short intervals downslope will concentrate runoff and effectively increase water in the root zone. A portion of the land may be more valuable for the runoff if it can contribute to soil water storage in the remaining area. The relation of available water to available nitrogen can be critical for grain or seed yields. Relatively moderate nitrogen availability with low water availability can be deleterious. In contrast, a positive forage or vegetative response to applied nitrogen is generally obtained under the dryland conditions.

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